10/089254
Rec'd PCT/PTO 28 MAR 2002

200012257

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Description

Switching device with an actuator element consisting of a shape memory alloy

The invention relates to a switching device with a strip-shaped actuator element consisting of a shape memory alloy, into which a predetermined shape has been impressed at an annealing temperature and which is connected to a movable contact part of a switching contact, and with means for heating up the actuator element above a temperature level bringing about an opening of the switching contact on the basis of a change in shape of the actuator element. A switching device of this type is disclosed by the publication "Engineering Aspects of Shape Memory Alloys", published by Butterworth-Heinemann, London (GB) 1990, pages 330 to 337.

Standard circuit-breakers, as are known for example as Siemens circuit-breaker standard range 5SX2/5SX4, have in their current path a magnetically quick-tripping short-circuiting switching contact. This switching contact additionally has a delayed trip for current limitation, in that it can also be thermally opened. For this purpose, a bimetallic strip which is connected to a movable contact part of the switching contact and is indirectly heated up when there is an overload is generally integrated into the current path. This heating-up is accompanied by a curving of the bimetallic strip, which leads to an opening of the switching contact. When the heating ceases, the bimetallic strip returns to its extended shape, closing the switching contact.

It is known from the publication mentioned at the beginning "Engineering Aspects of Shape Memory Alloys" to replace such bimetallic strips by strip-shaped actuator elements consisting of a shape memory alloy.

Actuator elements of this type must therefore undergo corresponding curving effects when they are

heated up. It is therefore considered necessary to impress a correspondingly curved shape into these elements at relatively high temperatures of, for example, 600 to 850°C. After triggering the shape memory effect at an elevated temperature, for example over 200°C, the transition into the impressed curved shape then takes place, while at lower temperatures, in an operating state in which the switching function is not triggered, between approximately room temperature and approximately 200°C, an extended shape of the actuator element is ensured by means of an additional spring element, so that a movable contact part of a switching contact mechanically connected indirectly to the actuator element then rests against a fixed contact part.

The production of a corresponding actuator element is relatively cost-intensive, however, because of the annealing at high temperature for the impressing of the curved shape.

It is therefore the object of the present invention to design the switching device with the features mentioned at the beginning in such a way that lower-cost actuator elements consisting of a shape memory alloy can be used.

This object is achieved according to the invention by providing an actuator element into which an at least largely extended shape has been impressed at the annealing temperature and which has a curved shape in the operating state in which the switching function is not triggered, and which rests between its one end, which is held fixed, and its other end, which is facing the movable contact part, on a deflecting element with frictional engagement in such a way that the deflecting element exerts on the concave inner side of the

actuator element a counterforce partially counteracting the curving of the latter.

Advantages associated with this configuration of the switching device can be seen on the one hand in that a low-cost annealing of the actuator element in an at least

largely extended, i.e. straight, shape (with the inclusion of slight deviations from this) is made possible, in particular in the rolled state of a corresponding metal sheet. The consequence of this is that the actuator element can assume a curved shape in the operating state at low temperature. The curving of the actuator element can in this case be achieved in various ways: either the actuator element has what is known as a 2-way effect on account of corresponding preparational conditions; i.e. two different shapes (curved and extended) have been impressed into it in a way known per se for the two different temperature ranges (of the operating state and triggering state), so that the element curves of its own accord at the lower temperature. Or in the case of actuator elements with what is known as a 1-way effect, the curved starting position must be ensured by a special (external) restoring spring. The force to be expended for this purpose is relatively low on account of the material. In the case of both types, however, it is found that, without the use of a deflecting element according to the invention, the electrical and mechanical connection of the actuator element at its fixed end to a part of the switching device is subjected to loading on account of a relatively high lever effect during its thermally induced change in shape. This is so since the customary alloys of actuator elements with shape memory properties tend on account of their general intermetallic crystalline structure toward brittle mechanical behavior, which specifically in the connecting technique required at the end mentioned, for example by means of welding or clamping, has disadvantageous effects on the quality of the corresponding contact point. However, corresponding disadvantages are at least largely eliminated by the use according to the invention of the deflecting element. This is so since this deflecting element is arranged such that it is fixed in such a way

that a force which attempts to bend the actuator element back in the direction of its extended shape is exerted on the actuator element that is in fact curving at the operating temperature. This counterforce is then discontinued when the actuator element is heated, in that the

actuator element goes over at least largely into its extended shape. This produces the major advantage of a mechanical relief of the actuator element in a mechanical connecting region (clamping point) of its fixed end during frequent movements for opening and closing the switching contact.

Since shape memory materials are generally not as low in cost as bimetal, it is generally attempted to reduce the use of material for corresponding circuit-breaker device with overcurrent trip by actuator elements consisting of shape memory material. Problems are encountered here when using corresponding actuator elements such as those in the prior art according to the cited publication "Engineering Aspects of Shape Memory Alloys" with regard to the mechanical stability at the clamping point if the strip-shaped actuator elements are designed to be too narrow and too thin. This is so since lever effects cause undesired deformations to occur at these elements, which can result in the failure of the switching contact. The partial bending-straight, according to the invention, of the actuator element by means of the deflecting element significantly counteracts this problem. This is so since the resting effect brings about the mentioned significant relief of the mechanical connection at the fixed end.

A further advantage of the use of a corresponding deflecting element is the way in which it governs the bending-straight of the actuator element. Since the connecting point at the fixed end of the actuator element represents a mechanical weakpoint on account of the lever arm and, although the strip-shaped actuator element would bend straight, the torsional moment at the contact point induces a curving effect, the use of a deflecting element of this type is indeed particularly important.

In addition, the actuator elements which can be used for the switching device are relatively low in cost. This is so because

the desired switching behavior can also be achieved with a significant reduction in the volume of the shape memory material, compared with the customary actuator elements, for example according to the publication cited at the beginning.

Advantageous configurations of the switching device according to the invention emerge from the dependent claims.

For instance, a restoring spring keeping its actuator element in its curved shape in the operating state may be provided in particular for the switching device. In this way, relatively low-cost actuator elements consisting of shape memory alloys with what is known as a 1-way effect can be used.

Furthermore, it is advantageous if the actuator element is connected to the movable contact part electrically by means of a stranded wire and mechanically by means of a switching linkage. Use of the stranded wire means that the mobility of the movable end of the actuator element is virtually unrestricted. The actuator element can consequently be integrated into a current path.

For further explanation of the invention, reference is made below to the drawing, in which:

figure 1 schematically shows the basic functional mode of an actuator element for use in a circuit-breaker

and

figure 2 shows a detail from an actual exemplary embodiment of a corresponding circuit-breaker.

In the figures, corresponding parts are respectively provided with the same reference numerals.

The actuator element 2 shown in figure 1, consisting of the known shape memory alloys, expediently has a strip or band shape. It consists at least partially of

one of the known shape memory alloys. Ti-Ni alloys are to be regarded as particularly suitable. For example, variously composed Ti-Ni and Ti-Ni-Cu alloys are disclosed by "Materials Science and Engineering", Vol. A 202, 1995, pages 148 to 156. Various $Ti_{50}Ni_{50-x}Pd_x$ shape memory alloys are described in "Intermetallics", Vol. 3, 1995, pages 35 to 46 and "Scripta METALLURGICA et MATERIALIA", Vol. 27, 1992, pages 1097 to 1102. It goes without saying that, instead of the Ti-Ni alloys, other shape memory alloys are also suitable. For example, Cu-Al shape memory alloys come into consideration. The corresponding CuZn24A13 alloy is disclosed by "Z. Metallkde.", Volume 79, issue 10, 1988, pages 678 to 683. A further Cu-Al-Ni shape memory alloy is described in "Scripta Materialia", Vol. 34, No. 2, 1996, pages 255 to 260. It goes without saying that further alloying constituents, such as Hf for example, can be alloyed in a way known per se in addition to the aforementioned binary or ternary alloys. For the exemplary embodiments explained below, it is assumed that a Ti-Ni shape memory alloy is selected.

In a way known per se, a predetermined shape has been impressed into the actuator element by means of annealing above 350°C, for example at a temperature between 400 and 850°C. According to the invention, an at least largely extended shape is to be produced at this temperature. This then leads to the actuator element at lower temperatures either attempting to assume a curved shape (in the case of the 2-way effect type), without any external force acting, or being made to curve by means of a very small external force (in the case of the 1-way effect type). These lower temperatures generally lie in a temperature range below 200°C, which can be regarded as the operating state in which a switching state is not yet triggered.

According to figure 1, a correspondingly curved, strip-shaped actuator element 2 is to be rigidly connected at an axial end 2a to a

fixed part 3, for example a housing part, of a switching device according to the invention, in such a way that a good mechanical and electrical contact with respect to the part 3 is ensured. At the opposite other end 2b of the actuator element 2 there is a movable contact part 4a of a switching contact 4. As assumed in the case of the exemplary embodiment represented, this contact part is either attached directly to the actuator element 2 or can be moved by the latter indirectly by means of a mechanism. An assigned fixed contact part of the switching contact is not shown in any more detail in the figure and is denoted by 4b.

According to the invention, the curving of the actuator element 2 is counteracted in the operating state, in that a counterforce G acts on its concave (curving) inner side between its two ends 2a and 2b. For this purpose, a fixed cylindrical deflecting element 5, known as a "deflecting pin", is provided. The arrangement of this "pin" is chosen in this case in such a way that the counterforce G partially counteracts the curving tendency of the actuator element 2. The deflecting element 5 thereby presses on the actuator element 2, for example approximately in its center between the two ends 2a and 2b. It is generally arranged at a distance A of a few centimeters, for example approximately 1 cm, away from the fixed end 2a. In this case it is intended by appropriate arrangement of the deflecting element 5 to exert a counterforce G of such a magnitude that a curving of the actuator element 2 still occurs at low temperatures. If the actuator element is then heated up beyond a temperature high enough for a switching function (by opening of the switching contact), in particular over 200°C, it assumes at least largely its impressed extended shape, indicated in the figure by a dashed line, passing over an angle of curvature or arc

α. The frictional engagement with respect to the deflecting element 5 is in this case at least largely overcome. As can be seen from the figure, the

position of the deflecting element 5 must consequently be chosen from the aspect of a displacement of the movable contact part 4a that is sufficiently large for contact opening. Choice of the position is governed here not only by the distance A from the fixed end 2a but also by the temperature of the heating or heating-up in the case of an overcurrent.

The heating may in this case take place in a direct way, in that a current I passed via the actuator element 2 leads to the heating-up of the latter on account of the ohmic resistance of this element. In addition, however, indirect heating-up is also possible, in that a current-dependent heating effect of a heating element which has a thermal effect on the actuator element 2 is brought about.

Figure 2 shows the parts of a switching device 10 essential for the invention. Where the parts are not shown in any more detail here, a construction of a known circuit-breaker is assumed (cf. the mentioned Siemens standard range of circuit-breakers 5SX2/5SX4). The switching device has, inter alia, the following parts, that is

- a short-circuiting trip with an electromagnet 11,
- a tripping rocker 12 of ferromagnetic material, which is mounted about a pivot point 13 and, in the case of short-circuiting, is attracted at one end by the magnet 11,
- a switching linkage 14, which is connected to the rocker 12 and to a movable contact part of a switching contact, which cannot be seen in the figure, and opens the switching contact or keeps it closed, depending on the pivoting position of the rocker,
- a mechanism 15 supporting the switching function of the switching contact, with various parts not shown in any more detail in the figure,

- a (copper) stranded wire 17 of a current path leading to the movable contact part of the switching contact,

- a fixed housing part 3 as part of the current path in the form of a steel frame

and

- a strip-shaped actuator element 2 consisting of a shape memory alloy, the fixedly-held end 2a of which is connected in an electrically conducting and mechanically secure manner to the housing part 2 and to the movable end 2b of which the stranded wire 17 is correspondingly securely attached. The tripping rocker 12 also acts on this end.

Since the actuator element 2 according to the chosen exemplary embodiment is intended to be of the 1-way effect type, as it is known, it also requires a special restoring spring 18, with the aid of which the tripping rocker 12, and consequently also the actuator element 2, are restored to the starting position of the operating state (at the lower operating temperature) or are kept in this position. The restoring force to be applied for this purpose by the spring 18 is relatively small.

The actuator element 2 is shown in figure 2 in its corresponding, closed position, in which the movable contact part, connected with its movable end 2b by means of the stranded wire 17, rests against the fixed contact part of the switching contact. The actuator element has in this case a relatively small curvature, since a counterforce G is exerted on its concave inner side by means of the deflecting element 5 located approximately in the center between the two ends of the actuator element, said counterforce being exerted for example via a film-like intermediate element 19, for example made of Kapton. By indirect heating of the actuator element, in particular in that a current passing via it goes into an overcurrent range and induces sufficient warming of the element on account of Joulean losses, the actuator element goes over into its

at least approximately extended shape, passing through an angle of curvature α. As it does so, it takes with it the tripping rocker 12 acting on its end 2b, so that the opening of the switching contact is brought about by means of the switching linkage 14 mechanically connected to the rocker, by the movable contact

part being lifted off the fixed contact part. An overcurrent trip of the circuit-breaker is performed in this way.